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Spatial Variation in Risk Preferences Among Atlantic and Gulf of Mexico Pelagic Longline Fishermen

IVAR E. STRAND, JR.
University of Maryland

Abstract *This paper shows the effects of spatially aggregating data in an analysis of fishing site choice among Atlantic and Gulf of Mexico longline fishers. Parameter estimates of expected utility, measures of risk, and estimates of welfare losses from area closures are presented. The estimated parameters and the measures of risk aversion indicate some spatial variation. However, the welfare measures from the area closure vary widely between a spatially aggregated model and a disaggregated model. The reason appears to arise from the economic behavior of fishers in New Jersey, where the expected utility model performs poorly.*

Key words Expected utility analysis, applied welfare analysis.

JEL Classification Codes C25, D61, D80, Q22.

Introduction

Fisheries economists may have ignored important differences in the behavior of commercial fishermen. Given the greater emphasis being placed on understanding and adjusting for the diversity in local fishing communities and in fishers, other social scientists spend great efforts to analyze the difference among spatially dispersed communities and even fishermen. Sociologists point out differences including spatial distributions in ethnicity, scale of operation, "corporate" structure, and other potentially important individual characteristics of firms. For example, the Highly Migratory Species Management Plan Chapter 9 (USDC 1999), contains an analysis by sociologists that defined several distinct groups of "communities" that fish highly migratory species with longlines. The implication of the analysis is that there is importance in considering the spatially distinct groups differently, especially when it comes to management.

The question remains as to whether the spatial heterogeneity in economic activity and behavior of individuals has any impact on traditional economic analysis associated with management strategies. If spatial heterogeneity does exist and is ignored, estimated regulatory impacts on the industry could be wildly inaccurate. An obvious focus for analyzing spatial differences is in risk preferences of fishers. Each time a captain puts to sea, a choice of where to fish is made and the choice may convey information about the captain's and/or owner's preferences toward risk. Economists are also recognizing the importance of spatial fishing decisions and the random nature of production (*e.g.*, Eales and Wilen 1986; Dupont 1993; Holland and Sutinen 2000; Curtis and Hicks 2000). Mistiaen and Strand (2000), using a mixed or

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Ivar E. Strand, Jr. is a professor emeritus in the Department of Agricultural and Resource Economics at University of Maryland, College Park, MD 24521 USA, email: ivars@arec.umd.edu.

random parameter logit, showed a significant difference in the variance of expected net revenue on site choice among longliners. However, they did not consider the geographic distribution of behavior nor attempt to link the differences to characteristics of fishers.

In this paper, spatially defined groups are used to determine differences in fisher's behavior toward economic risk. The paper is meant to be an exploratory examination of the spatial distribution of risk preferences and as such, uses a stylized model of fishing behavior. A fundamental model of expected utility maximization is used in a discrete choice framework, analyzing fishing activity for different spatially located groups of fishermen. The paper is divided into seven sections, a description of the fishery, the fundamentals of choice under uncertainty, the statistical methods used to assess spatial risk preferences, the data construction, the empirical results of applying the statistical methods, and the limitations and conclusions.

Descriptive Data

The pelagic longline fishery of the Atlantic and Gulf of Mexico has vessels operating out of ports distributed from Massachusetts to Texas.[1] After discussion with the Advisory Panels for Highly Migratory Species and for Billfish, sociologists chose five communities to examine based, in part, on geographic spread. The communities were (*i*) Gloucester and New Bedford, Massachusetts, (*ii*) Barnegat Light and Point Pleasant, New Jersey, (*iii*) Hatteras and Wanchese, North Carolina, (*iv*) Islamorada (in the Florida Keys), Pompano Beach (East Coast of Florida), Madeira Beach (West Coast of Florida), Panama City (Florida Panhandle), Florida, and (*v*) Dulac and Venice, Louisiana. The analysis suggested a great variety of activity and diversity in the economic structure and importance of fishing to the local communities.

I follow their general approach, but extend the number of locations studied by defining "homeport regions" based broadly on state boundaries. However, Florida is segmented and New England states, as well as Virginia and Maryland, are combined. A vessel and its annual activity were assigned to a "homeport region" based on the reported homeport of the vessel owner in their application for a pelagic longline permit.[2] Table 1 shows the homeport regions and the average characteristics of vessels reporting from a particular homeport.

An important implication of the homeport assignment is that a vessel need not take the majority of its trips from that homeport region. For instance, less than one-third of the longline trips taken by New England vessels departed from a homeport in New England (table 1). Vessels in this region reported longlining in New England in the summer and in the South Atlantic in the late fall. Thus, the definition predicates risk preferences on the basis of the residency of the economic agent rather than the geographic circumstances of the choice. Not all homeport regions have such a large out-migration as New England. Vessels designated in Southeast Florida, the Florida Panhandle, and Texas had nearly every trip departing from that homeport region.

A second feature of table 1 is the spatial variation in importance of pelagic longlining operations by the vessels. At the extreme of the geographic range, the vessels are generally less dependent on pelagic longlining. Vessels homeported in

[1] These vessels also have been active in the Caribbean and as far south as Uruguay. I consider only those with homeports on the East Coast or Gulf of Mexico.

[2] A definition of homeport based a trip's departing port rather than a vessel's reported homeport was also attempted. The results did not vary greatly.

Table 1
Characteristics of Longline Vessels, by Region, 1996

Homeport Region	Reporting Vessels	Percentage of Trips Left from Region	Reported Longline Trips per Year	Minimum, Maximum, Median No. of Trips	Vessel Length (feet)	Cost per Mile at Sea ($/mile)
New England (ME to CT)	8	27.6	3.6	1,12,1	64.6	1.67
New York	15	49.5	7.2	1,20,6	55.7	1.30
New Jersey	21	68.7	5.5	1,14,4	61.1	1.40
Maryland/Virginia	6	65.5	9.1	2,19,8	59.7	1.30
North Carolina	13	82.7	10.2	3,25,10	51.9	1.02
South Carolina	5	98.9	17.4	7,29,17	57.7	1.34
Florida Northeast	9	69.9	8.1	2,14,6	46.5	0.92
Florida Southeast	27	95.6	16.7	1,49,15	46.1	0.87
Florida Keys	5	47.4	7.6	1,14,8	52.9	1.50
Florida Southwest	12	62.7	5.6	1,14,3	49.4	0.88
Florida Panhandle	13	98.7	6.8	1,17,7	55.0	1.10
Louisiana	32	74.2	5.3	1,14,7	70.4	1.67
Texas	7	100.0	5.6	1,9,2	68.0	1.55

Note: Region is defined on the basis of homeport. Florida areas are defined as Northeast (north of Fort Pierce), Southeast (Fort Pierce to the Keys) the Keys, Southwest (north from the Keys to Tampa), and the Panhandle (north from Tampa to Mississippi).

Louisiana/Texas and New England, for instance, take the fewest reported trips, whereas vessels in southeast Florida take the greatest number of trips. Given that tuna and swordfish annually migrate out of the Gulf of Mexico into the Atlantic and back, one might expect this pattern.

When the average longlining trip is considered according to geographic location of homeport, other interesting characteristics emerge. Table 2 shows that the average miles of longline per set and the days at sea for trips from the extreme geographic range are greater than for trips of vessels with homeports in the center of the geographic range. The vessel owners at the extremes of the range may want to produce at the intensive margin because the season and activity is reduced by the migratory nature of the stock. Another interesting feature of table 2 is the manner in which tuna and swordfish revenues vary across homeport. There is a dramatic difference between vessels with homeport in South Carolina, which capture primarily swordfish, and vessels in North Carolina, which capture primarily tuna. Tuna tends to be the primary species north of North Carolina, whereas swordfish dominates from South Carolina to the Keys. Oddly, the use of light sticks[3] does not always imply targeting of swordfish—South Carolina vessels use relatively few light sticks per trip, yet have the greatest revenues per trip from swordfish. In the Gulf of Mexico, tuna becomes the primary species. About 85% of the trips in the Gulf were taken to the same area that was fished on the previous trip, and less than 3% of the trips returned to a new port. Trips from vessels with homeports other than the Gulf returned to the previous fishing site less than 60% of the time. Vessels home ported in the Northeast are more active in changing ports and their fishing locations.

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[3] Light sticks are used on longlining vessels to attract fish to the bait. It is generally thought that the technology works best with swordfish.

Table 2
Characteristics of Longline Trips, by Region, 1996

Homeport Region	# of Trips Observed	Number of Sets	Main Line Set (miles)	Number of Light Sticks	Trips Switched Homeport	Trips Made to Previous Site	Swordfish Revenues ($)	Tuna Revenues ($)	Estimated Trip Costs to Boat ($)	Days at Sea
New England	29	6.31	20.2	204	10.3%	55.2%	4,024	3,276	3,514	9.3
New York	109	6.47	25.3	323	11.9%	58.7%	3,921	6,424	4,247	9.4
New Jersey	115	8.18	25.2	88	9.6%	51.3%	3,679	8,490	5,128	12.0
Maryland/Virginia	55	5.31	17.4	108	5.5%	72.7%	2,595	3,919	2,760	7.3
North Carolina	133	3.74	18.2	88	5.3%	67.7%	1,867	4,479	2,145	6.2
South Carolina	87	5.40	19.2	70	1.1%	90.8%	6,177	914	2,820	7.8
Florida Northeast	73	5.18	16.4	31	2.7%	56.2%	3,401	2,385	2,374	8.0
Florida Southeast	451	3.59	16.6	281	6.2%	70.7%	3,414	823	1,902	5.0
Florida Keys	38	2.37	15.7	182	2.6%	78.9%	2,658	735	1,338	3.3
Florida Southwest	67	5.30	21.9	264	1.5%	83.6%	2,337	3,416	3,043	9.1
Florida Panhandle	89	5.60	25.3	145	1.1%	86.5%	2,181	5,584	3,675	9.3
Louisiana	229	5.31	28.7	119	2.2%	76.0%	1,856	8,962	4,048	12.9
Texas	29	5.55	42.6	65	3.4%	89.7%	1,619	8,106	5,689	11.1

Notes: Region is defined on the basis of homeport. Florida areas are defined as Northeast (north of Fort Pierce), Southeast (Fort Pierce to the Keys) the Keys, Southwest (north from the Keys to Tampa), and the Panhandle (north from Tampa to Mississippi).

Figure 1 also illustrates the geographic distribution of fishing activity in the Atlantic and Gulf of Mexico during 1996 by showing the reported location of each set. Of particular interest to the industry is the Atlantic Ocean's Gulf Stream. Sets are made along its western edge as the upwelling of nutrients at the edge attracts smaller fish on which swordfish and tuna feed.

The Expected Utility Analysis in the Context of Fishing Choice

The captain (and/or owner) is assumed to make a spatial choice involving random production each time they put to sea. A traditional way to analyze decision making in the presence of uncertainty is the Von Neumann-Morgenstern expected utility analysis (Von Neumann and Morganstern 1944). The agent is assumed to maximize expected utility by choosing amongst alternative lotteries. In the fishery, the short-run choice involves choosing an area to fish. The choice of an area is inherently the choice of a lottery, and the set of areas is the choice set of lotteries.[4] The basis for the choice is the owner/captain's expectation of utility associated with the returns in each of the areas.

More formally, the agent is assumed to have a utility function, $u(.)$, over the sum of initial wealth (W) and a return (Z).[5] The return in a given area is a random variable with the density function $F(Z)$. The Von Neumann-Morganstern expected

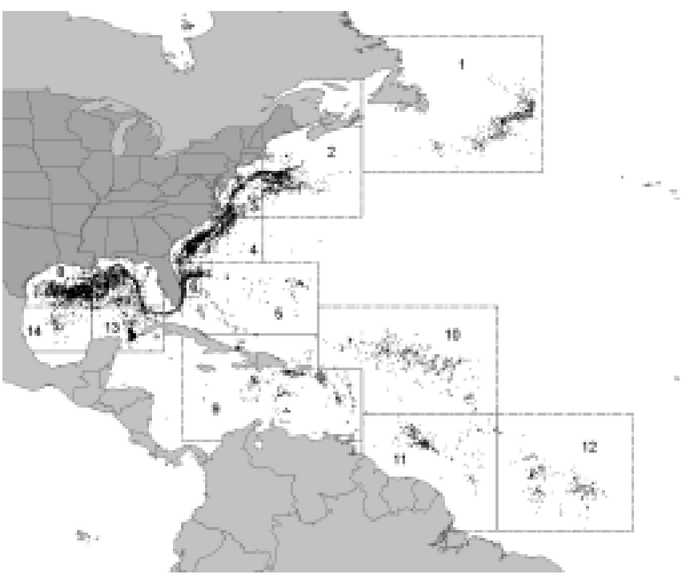

Figure 1. Location of Sets and Area Designations, 1996

[4] Bockstael and Opaluch (1983) first used this analysis in the context of an entire season's choice of which fishery to fish.
[5] A far more complete discussion of expected utility analysis can be found in Mas-Colell, Whinston, and Green (1995), which addresses issues such as the assumed properties of the expected utility function.

utility function for a given area is then $U(F) = \int u(W + Z)\, dF$. On each trip, the captain's choice of area will yield information on the parameters of the utility function and hence the preferences regarding risk. A trip to a given site is a choice among lotteries, with a distribution of returns $F(Z_j)$ associated with the jth area. If the captain (and/or owner) maximizes expected utility, then the actual choices among the sites can be used to estimate parameters of the utility function. The model assumes that the choice of site depends on expected utility, the array of discrete alternatives, the distribution of returns, and a specification for utility. The firm is assumed to choose the one alternative with the highest expected utility. On a choice occasion (in our case a trip, t), the captain is assumed to have a choice among J sites and to solve the following conditional expected utility maximization problem:

$$V_t^* = \underset{j=1,\ldots,J}{Max}\left\{E\overline{U}_{1t} + \varepsilon_{1t}, \ldots, E\overline{U}_{Jt} + \varepsilon_{Jt}\right\}, \tag{1}$$

where the expression $E\overline{U}_{1t}$ is the deterministic portion of the expected utility function. An error term, ε_{jt}, is introduced because the researcher does not know all of the information that the economic agent has and uses in their choice of a site. A second-order approximation of the expected utility function for the jth site is:

$$E\overline{U}(W_j) \approx \overline{U}\left[W^0 + E(Z_j)\right] + \frac{1}{2} * \frac{\partial\overline{U}\left[W^0 + E(Z_j)\right]}{\partial W^2} * \sigma_j^2(Z_j), \tag{2}$$

where $\sigma_j^2(Z_j)$ is the variance of net revenues at the jth site.

Several definitions of risk preference typically are used and will later be used to characterize the risk preferences of fishers in a particular area. A risk-averse person will have a concave utility function that implies they will not take an actuarially fair gamble. The utility gained from winning a fair gamble is less than the utility lost from losing it. The Arrow-Pratt measure of absolute risk aversion is:

$$R(W) = -\frac{\partial^2 U / \partial W^2}{\partial U / \partial W},$$

where $U(.)$ is the utility of wealth and the derivatives are taken at a specific level of wealth. The absolute risk aversion value measures the curvature of the utility function and is invariant to scalar changes in the measurement of utility. An alternative, the relative risk aversion measure, is given by:

$$R^*(W) = -W\,\frac{\partial^2 U / \partial W^2}{\partial U / \partial W}.$$

It considers gains and losses as proportions to wealth. Finally, we can define the risk premium as an amount of money that would make the decisionmaker indifferent between the risky alternative and its certainty equivalence. The risk premium is an amount (M) that the individual would pay to assure receiving the risky alternative's expected value as opposed to taking the gamble. Pratt approximates this premium by:

$$M(W, \tilde{Z}) = \frac{\sigma^2 R\left[W + E(\tilde{Z})\right]}{2}.$$

With estimated parameters of a utility function, the three different measures of risk aversion can be computed.

With the parameters of the expected utility function, it is also possible to estimate the losses associated with such a closure. Hanemann (1982) showed the closed-form solutions of welfare change for the maximum expected utility functions in several cases where the marginal utility of income was constant. However, the closed-form solutions cannot be used in our case because the marginal utility of income is presumed to change with wealth. However, one can determine an equivalent variation by an iterative procedure that that equates expected utility before and after the choice set is reduced:

$$\begin{aligned} EV &= \left\{ EV \middle| V^1\left[W^0 + E(\pi^0), \sigma_a^2(\pi)^0\right] = V^0\left[W^0 + E(\pi^0) + EV, \sigma_a^2(\pi)^0\right] \right\} \\ &= \left\{ EV \middle| \log\left(\sum_{a \in A'} e^{U_a\left[W^0 + E(\pi_a^0), \sigma_a^2(\pi_a)^0\right]} \right) = \log\left(\sum_{a \in A} e^{U_a\left[W^0 + E(\pi_a^1) + EV, \sigma_a^2(\pi_a)^0\right]} \right) \right\}. \end{aligned}$$

The equivalent variation is the willingness to pay to avoid the area closures. This welfare measure is employed in other studies of fisheries closures (Curtis and Hicks 2000).

The Operational Model

With this theoretical framework, we can now explain the specifics of the process by which the risk preferences of longliners can be. A quadratic utility function is used and equation (2) becomes:

$$EU(W_j) = \alpha\left[W^0 + E(z_j)\right] + \beta\left\{\left[W^0 + E(z_j)\right]^2 + \sigma_j^2(z_j)\right\}. \tag{3}$$

The expected return and its variance in this expression are based on previous information from fleet operations. We chose not to include initial wealth for several reasons:

1. Determining the initial wealth of agents is nearly impossible;
2. Introducing error into the highly correlated terms in the utility function creates severe statistical problems;
3. Experiments (*e.g.*, Kahnemann and Tversky 1984) indicate that choices in lotteries are independent of initial wealth.

The specification of the utility function used in the estimations is then:

$$EU(W_j) = \alpha\left[E(z_j)\right] + \beta\left[E(z_j)^2 + \sigma_j^2(z_j)\right]. \tag{4}$$

The expected utility needs only an expected return [$E(Z_j)$] and a variance (σ^2)[6] associated with each area considered. With this specification, the choice of the *k*th site is the solution to problem (1) if:

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[6] Higher moments of the distribution could be used, but are not in our analysis.

$$\alpha\left[E(z_{kt})\right] + \beta\left[E(z_{kt})^2 + \sigma_k^2(z_{kt})\right] + \varepsilon_{kt} \geq \alpha\left[E(z_{jt})\right] + \beta\left[E(z_{jt})^2 + \sigma_j^2(z_{jt})\right] + \varepsilon_{jt} \quad (5)$$

$$\forall\, k \neq j, j = 1,\ldots,J_t \text{ on occasion } t.$$

These statements and the assumption that the error term has a type 1 extreme value distribution lead to the probability statement:

$$\Pr_{kt} = \frac{\exp\ (E\overline{U}_{kt})}{\sum_{j=1}^{J_t} \exp\ (E\overline{U}_{jt})} \quad \forall\, k = 1, \ldots J \text{ on occasion } t. \qquad (6)$$

For each trip, we know which site was chosen and its probability of being chosen is 1. We let an index $d_k = 1$. Those sites that are not chosen have a probability of 0 or $d_k = 0$. For the nth homeport area having T_n trips, the estimation is:

$$\underset{\alpha_n, \beta_n}{\text{Max}} \quad \log(L) = \sum_{t=1}^{T_n} \log\left\{\prod_{k=1}^{J_t}\left[\frac{\exp\ \left\{\alpha_n\left[E(z_{kt})\right] + \beta_n\left[E(z_{kt})^2 + \sigma^2(z_{kt})\right]\right\}}{\sum_{j=1}^{J_t} \exp\ \left\{\alpha_n\left[E(z_{jt})\right] + \beta_n\left[E(z_{jt})^2 + \sigma^2(z_{jt})\right]\right\}}\right]^{d_k}\right\}. \qquad (7)$$

This model is used to estimate the parameter, α_n and β_n for each of the designated homeport regions.

Later in the paper, the estimated losses associated with closure of an area are explored. Using the estimates of the utility function $(\hat{\alpha} \text{ and } \hat{\beta})$ from applying equation (7), the estimated welfare loss on a trip associated with a change in the opportunity set from J_t to J_t' is given by:

$$EV = \left\{\log\left(\sum_{j \in J_t'} e^{\hat{\alpha}(\pi_j + EV) + \hat{\beta}\left[(\pi_j^2 + EV^2) + \sigma_j^2\right]}\right) = \log\left(\sum_{j \in J} e^{\hat{\alpha}\pi_j + \hat{\beta}(\pi_j^2 + \sigma_j^2)}\right)\right\}, \qquad (8)$$

where EV is the amount of money that will offset the loss in utility from a reduced choice set. Although this measure may have a bias (McFadden 1995), the nature of this problem reduces the likelihood of a large bias on the estimates.

Data Construction

The process of constructing data to make the fishing activity consistent with the theoretical model is not trivial. The randomness is assumed to arise from the spatial variation in stock. This variation is reflected in average catches per mile of mainline during a set of longline.[7] The operator was assumed to know how much line and

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[7] I will use the term set-mile to denote the number of sets times the miles of mainline on a particular trip.

how many sets would be made when they left port. The number would not vary across sites. With these assumptions, the expected revenues and trip costs associated with choosing a site can be constructed.

The mean and variance for revenue per set mile are constructed for each area during each week of 1996 based on actual observations. Each reported set on a trip in 1996 was considered (the location of the sets is shown in figure 1). The expected value of revenue per set-mile and its variance was computed for the sum of trip harvests from tuna and swordfish for each of the 14 water areas (sites) shown in figure 1. These values are used to construct the expected net revenue, $E(z_{kt})$, and its variance, $\sigma^2(z_{kt})$, for each of the tth trips at the kth fishing location/landing port for all trips in the nth homeport region.[8] The average harvest per set-mile was multiplied by the set-miles on the actual trip to obtain the expected harvest per trip from fishing at a given site. Prices were multiplied by harvest to obtain revenues. The variance in revenues per set-mile was also expanded to the trip by multiplying the square of set-miles by the variance of revenue per set-mile. The expected value and variance of revenues were computed for each week of the year for each of the fishing location/landing port combinations. For a given trip, the expectation and its variance were computed based on the previous three weeks of fishing activity at a given harvest area/landing port combination. The expectation and variance for a site for an upcoming trip was computed as a weighted average of past three weeks' activity with higher weights given to the less distant past. The development of expected net revenues required generating not only expected net revenues and variance of net revenues for a vessel's actual site/port chosen, but also generating the net revenues and variances for the site/port that could possibly be chosen.

It was also necessary to develop trip costs.[9] In 1997, a plurality of boats used a 50% share system, meaning that 50% of the net revenues from a trip go to the owner of boat (Porter *et al.* 2001).[10] Based on that information, the expected net return to the decisionmaker is given by $E(Z_{jt}) = 0.5 * [E(z_{jt}) - C_{jt}]$. The development of costs, C_{jt}, is based on the assumption that the fishing behavior would be independent of the area chosen. This means that the fishing activity (*i.e.*, number of sets, bait and light sticks used, and miles of mainline) do not vary across areas.

Travel expenses from a vessel's homeport to each of the feasible alternative fishing locations vary and were estimated in three stages, the estimation of: a vessel's fuel consumption per mile, a vessel's cost per mile, and the distance traveled from a homeport to each of the feasible site/port combinations. Fuel consumption per mile was estimated consistent with Mistiaen and Strand (2000), except that they misreported the relationship between fuel consumption and vessel length. The correct relationship is:

$$\underset{(-10.16)}{\text{Log(fuel/mile)} = -1.57} + \underset{(13.09),}{0.033} \text{ *vessel length} \qquad \text{Rbar}^2 = 0.61, \text{ Obs} = 107$$

where the values in parentheses are t-values under the null hypothesis of no effect. The cost per mile for each vessel was determined using fuel consumption per mile multiplied by cost per gallon. The cost per gallon data were obtained from the economic survey and were the averages for all reporting trips in a region.

The next step was to compute distances from each vessel's initial homeport to

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[8] No consideration was given to potential correlation among trips for each captain/owner within a homeport region. Instead, each trip of vessels designated in a homeport region was treated the same.

[9] Trip costs represented approximately 80% of all annual costs of an average pelagic longline vessel in 1997 (Porter *et al.* 2001).

[10] A plurality of boats also included all trip costs when determining net revenue.

each alternative fishing ground/landing port. Centroids based on each vessel's sets were computed for each trip to obtain an "average" location fished for each of the 14 fishing locations (see figure 1). These centroids then were averaged across all trips in a given fishing area to use as the point to which the vessels would travel. Thus the "travel" distance for each vessel was from the actual homeport port to a centroid of a fishing area and then to a landing port (whose location was based on the average "location" of vessels landing in that area). Straight-line distances could not always be used because vessels had to avoid going aground on land areas, such as Florida. Thus, linear segments approximating travel routes were devised to avoid the land areas.

Another component of trip costs is that associated with gear (primarily hooks), bait, and light sticks. The gear and bait costs per trip from the survey (Porter *et al.* 2001) were regressed against the set-miles per trip with the following result:

$$\text{Bait and gear cost per trip} = \underset{(1.21)}{248} + \underset{(20.03)}{20} \text{ *set-miles} \qquad \text{Rbar}^2 = 0.82, \text{ Obs} = 85$$

where the values in parentheses are t-values under the null hypothesis of no effect. The number of light sticks on a given trip was computed from the actual light sticks used per set on each 1996 trip multiplied by the average cost per light stick ($0.55/stick) to yield the light stick costs per trip.

In keeping with the requirements of expected utility analysis, no trip with negative expected net revenues was used. Of the actual trips, this represented about 10% of the trips. Of those trips, about two-thirds reported less than three sets, suggesting an unusual circumstance, such as engine failure or bad weather.

Results

The Estimated Coefficients

Table 3 contains the estimates of α and β for each homeport region and for an aggregate of all Atlantic Coast homeports. The equations were estimated on the basis that both terms associated with β in equation (3) had the same effect. Estimated, but not reported, were equations in which the coefficient on variance was not restricted to be equal to the coefficient of the second term of equation (3).

The expected concavity ($\alpha > 0$ and $\beta < 0$) was realized for all homeports except for the trips taken from Louisiana and the Florida Panhandle. The statistical significance of the coefficients varied substantially across the homeports, owing, in part, to the relatively small sample sizes that emerged because of the geographic disaggregation. The quadratic form expansion of the utility function creates substantial correlation between the expected profit and the quadratic expression (simple correlation coefficients ranged between 0.65 and 0.85). Because of this, states with larger fleets generally produced more statistically significant coefficients. When the model was estimated with three coefficients, one could reject that the two estimates were different in all cases, although in several cases the coefficient on the variance term was not significantly different from 0. Multicollinearity among regressors undoubtedly accounted for much of the large variation in the estimated coefficients.

It is worth speculating as to why the model performed so poorly for homeports ranging from Tampa, Florida, through Louisiana. It is possible that groups of vessels normally fish in certain areas and information is shared within the group but not across groups. It could also be that a large percentage of vessels (68% in Southwest,

Table 3
Estimated Random Utility Parameters

Homeport Region	Estimated Coefficients (t-ratio) Net Revenue ($\$10^{-3}$)	Quadratic Term (10^{-6})	Pseudo r-squared (Choices, Trips)
New England	0.402 (1.84)	–0.018 (–1.63)	0.30 (228, 27)
New York	0.324 (3.14)	–0.023 (–3.27)	0.35 (795, 106)
New Jersey	0.037 (0.10)	–0.00081 (–0.30)	0.27 (918, 110)
Maryland/Virginia	0.233 (1.94)	–0.00420 (–1.24)	0.34 (393, 53)
North Carolina	0.328 (4.18)	–0.00291 (–2.23)	0.39 (744, 105)
South Carolina	0.181 (1.54)	–0.0108 (–1.55)	0.17 (599, 76)
Florida Northeast	0.220 (1.72)	–0.0080 (–1.49)	0.28 (603, 70)
Florida Southeast	0.257 (7.21)	–0.0171 (–5.5076)	0.35 (2,849, 389)
Florida Keys	1.22 (2.50)	–0.0432 (–1.69)	0.44 (189, 32)
Florida Southwest	0.0176 (0.16)	–0.00383 (–0.94)	0.26 (538, 60)
Florida Panhandle	–0.178 (–2.04)	–0.0018 (–0.82)	0.29 (624, 73)
Louisiana	0.019 (0.73)	0.0019 (0.99)	0.29 (1,654, 205)
Texas	0.214 (1.73)	–0.0083 (–1.71)	0.29 (218, 26)
ALL ATLANTIC HOMEPORTS (excludes Florida Keys)	0.071 (2.94)	–0.0013 (–2.28)	0.33 (7,129; 936)

Florida and 59% on the Panhandle of Florida) never change areas fished. Perhaps a greater refinement in the definition of fishing area would improve the results. Nevertheless, there does appear a consistency across homeport regions with respect to concavity and, hence, risk aversion.

For a comparison with a model in which no spatial consideration was given, the final row of table 3 has the estimates for a sample pooled over all areas except homeports from the Florida Keys through Texas. The aggregate estimates imply concavity and risk aversion and generally show less responsiveness to expected revenues and variance than do the estimates from samples of individual areas.

The Estimated Risk Measures

Table 4 contains estimates of several risk measures, each giving a slightly different perspective of the risk preference in the regions shown in column 1. The Arrow-Pratt relative risk-aversion measure shown in column 2 includes the estimated

Table 4
Measures of Risk Preference, by Homeport Region, 1996

Homeport Region	Median Arrow-Pratt Relative Risk Aversion	Median Risk Premium per Trip ($/trip)	Median Risk Premium per Set ($/set)	Median Risk Premium as a Percentage of Trip Costs
New England (ME to CT)	0.18	142	33	5.6%
New York	0.71	377	72	11.0%
New Jersey	0.18	269	29	5.0%
Maryland/Virginia	0.07	79	13	2.6%
North Carolina	0.03	30	8	1.3%
South Carolina	0.28	219	44	8.1%
Florida Northeast	0.14	139	27	5.1%
Florida Southeast	0.13	66	27	4.9%
Florida Keys	0.06	31	14	2.1%
Florida Southwest	0.21	140	68	8.1%
Florida Panhandle	NA	NA	NA	NA
Louisiana	NA	NA	NA	NA
Texas	0.35	531	74	10.5%
ALL ATLANTIC HOMEPORTS (excludes Florida Keys)	0.07	55	11	2.1%

Notes: Estimates based on coefficients for expected net revenue and variance of choices that were the selected choice on the previous trip.

parameters of the utility function along with the expected net return of the trip (remember, wealth is assumed to be 0). Fishermen from New York, principally Long Island, have the greatest average relative aversion to risk, whereas fishers in the Florida Keys are estimated to have the lowest. This measure, by itself, provides much information about risk preferences, but other measures may be more reflective of the preference with respect to the circumstances faced.

In column 3, the median[11] value of the risk premium per trip is shown for the alternative chosen on a given choice occasion. This measure contains both the relative Arrow-Pratt measure and the variance of the selected alternative. It represents a willingness to pay to insure against the randomness of the expected value per trip. It is an *ex post* measure in this case under the assumption that we know the parameters of the utility function with certainty and that we know which choice was made. The median over the choices made from vessels at a given homeport area vary, from a low of about $30 per trip in North Carolina and the Florida Keys to a high of over $500 in the Texas region. The premium is a function of variance in net revenues that is rather high in Texas, averaging over three times the variance in North Carolina.

The difference in variance is, in part, related to the type of trip that is taken in the different regions. The trips in each region vary in length and expenses incurred. To make the risk premium more comparable, each trip's estimated risk premium is divided by the sets made during the trip and by trip expenses. The median for each region is presented in columns 4 and 5. When considered on a per-set basis, the differences among areas are reduced considerably, with 9 of the 12 regions having a

[11] The median is used instead of the mean because it has a smaller variance. In some cases, extreme outliers skew the estimated distributions considerably.

value less than \$50/set. Texas still has the largest value, resulting primarily from the large variances associated with the sites that were chosen.

To show the risk premium in comparison to explicit costs of the trip, each trip's risk premium was divided by the estimated cost of the trip. The median risk premium was no more than 11% of trip costs in any region. The lowest percentages were found in North Carolina, Maryland/Virginia, and the Florida Keys, where the risk imposed was less than 3% of the trip costs. The largest percentage occurred near the extremes of the geographic range, in Texas and New York. Because of the species' migratory nature, these areas will likely face the greatest variance when the species move in and out of the areas. Operators in these areas were also estimated as having relatively high aversion to risk. The combination of these two factors contributed to the relatively high "inconvenience" of risk.

Finally, the last row shows our measures based on the pooled sample. Because of the estimates of utility function parameters, the relative risk aversion measure was small, especially in comparison with the entire sample. The low risk aversion estimate carried throughout the other measures, indicating a small risk premium per set at sea (\$8/set) and a small inconvenience factor (2% of trip costs).

Estimated Losses Associated with Area Closures

One of the advantages of the expected utility analysis is that utility-based welfare measures from policy changes are possible. For example, the National Marine Fisheries Service (NMFS) will sometimes consider closing areas to reduce the pressure on swordfish or tuna stocks. To examine the effect of disaggregating into homeport regions, the welfare associated with closing area 2 (figure 1) was examined using both the estimated parameters associated with the homeport and the parameters associated with the aggregate model. The results are shown in table 5.

Generally, the median welfare loss per trip is much larger with the aggregate model than with the homeport model. The average loss per trip for the homeport

Table 5
Welfare Measures of Closing Area 2 (figure 1) during 1996, by Region

	Regional Homeport Model		Aggregate Model	
Homeport Region	Median Welfare Loss per Trip (\$)	Percentage Loss of Expected Profit at Site Selected	Median Welfare Loss per Trip (\$)	Percentage Loss of Expected Profit at Site Selected
New England (ME to CT)	500	33%	2,150	107%
New York	200	5%	1,900	44%
New Jersey	4525	71%	2,375	48%
Maryland/Virginia	600	21%	2,400	77%
North Carolina	400	9%	2,300	50%
South Carolina	575	12%	1,350	32%
Florida Northeast	175	7%	675	13%
Florida Southeast	0	0%	0	0%
Aggregate Annual Loss All Atlantic Homeports	\$724,500		\$1,439,200	

model was about one-fifth of the value of the aggregated model. The one exception is New Jersey, which estimated an especially large loss of $4,525/trip with the disaggregate model, whereas the aggregate model generated a more reasonable expected loss of $2,375.

The exception helps the results. Essentially, the expected utility model did not explain the site choice for the New Jersey trips nearly as well as it did for the other states. Not only did it not explain the choices well, the coefficients associated with the utility function were an order of magnitude smaller than the estimates for other homeport regions on the East Coast. The large error associated with New Jersey was introduced into the estimated parameters of the aggregate model and had the effect of reducing the parameter estimates (*i.e.*, the responsiveness to expected profit and its variance). Because the vessels were not estimated to respond greatly within the aggregate model, the estimated welfare lost from closing an area was relatively larger. The vessel owners were considered more reluctant to move within the aggregate model and an area closure will lead to a larger disutility and estimated costs.

Limitations

As with any empirical work, the results must be considered within the situational context, restricting the bold claims that could be made about their generality. The most fundamental part of the analysis, the expected utility framework, must certainly be scrutinized for its relevance to decision making in fisheries. For example, the Allais paradox indicates an inconsistency between expected utility-maximizing behavior and commonly observed choices of individuals. Eggert and Martinsson (2002) also have raised a number of potential problems of the expected utility approach within fisheries, the most germane being the relatively small gamble (in terms of lifetime income) that a captain or owner makes regarding the spatial location of a trip. In cases of repeated small gambles, the rational approach reduces to maximizing expected profits (Arrow 1971; Rabin 2000). Eggert and Martinsson (2002) suggest that models of loss aversion and narrow bracketing may be superior to the expected utility analysis when considering small gambles.

While these comments do apply, the stakes on a typical longline trip are not that small, and the model employed is more of a "narrow bracketing" version of expected utility analysis. In 1997, for example, the average net operating return per trip in the pelagic longline fishery was about $3,400 (Porter *et al.* 2001). If the crew payments are also included (assuming that the crew are involved in the decision process), then the average return rises to nearly $7,500 per trip. While these may be relatively small compared with lifetime earnings, they are substantially larger than the average commercial fishing trip. Moreover, the results did not use a wealth component but instead used only the net returns associated with the gamble. In this way, I was assuming fishermen were narrow bracketing by using only one trip at a time (Eggert and Martinsson 2002). This may be the manner in which fishermen make their spatial location decisions. It is, however, not strictly the traditional expected utility analysis that considered the choice within the context of a lifetime stream of income.

Another issue that deserves attention is site definition. By and large, NMFS designations for ocean sites were used. These are likely too large if narrow specificity of fishing location is desired. I made no effort to reduce the site size, with the exception of doubling to four the number of sites in the Gulf of Mexico.

I also tried to simplify the definition of fishing groups, relying on homeports as defined mostly by state borders. Clearly there are other non-homogeneous characteristics of the pelagic longline fleet. Vessel size, type/extent of vessel loan, and ethnicity of owner/captain are among the characteristics that might influence risk preferences.

Conclusions

Although this research was largely exploratory in nature, it does indicate that risk preferences and the cost of risk vary spatially. The choice of fishery enhances the likelihood of this finding, and it is wise not to generalize the finding across fisheries. The pelagic longline fishery extends over a coastline of nearly 2,000 miles and harvests species that annually migrate even further. Thus, there is a potential for large spatial variation in the risk that fishers take. This is not true for an inland sea fishery, like Chesapeake oysters. Because of the sedentary nature of some species (small distances between harvesting areas and the constant "sampling" of the stocks), the variation of harvest is quite small and constant. The "gamble" that occurs in these fisheries is small, and economic literature suggests that maximizing expected profit is the rational strategy. It is not likely that one could detect risk preferences, much less spatial variation in them. Moreover, there may be a sample selection problem, as the most risk averse fishers might choose to be oystermen. There would be little variation in risk preference in such a sample.

The exercise revealed a number of difficulties with analyzing risk behavior. Initially, one must choose the nature of the decision. It could be the decision on entry and exit, the location of the homeport, the type and amount of gear used, the location of a trip, or the location of a set. I focused on the location of a trip, making that choice conditional on a number of other choices. One must confront the problem of estimating initial wealth. I chose to use "no wealth" as the initial position. This was because the other alternatives of predicting wealth were worse, and there is some reason to believe that myopic decisions are made. The decision regarding size of site and the relevant choice set is inherent in all RUM models, but when the spatial area is as immense as this one, it is particularly critical. One needs a sufficiently large site size so that expected returns and variances can be calculated simply but not so large that the sensitivity to the characteristics of a site is lost. The choice set also should reflect realistic alternatives considered by the fisher. These researcher choices make the results conditional. Hopefully, the results obtained in this paper reflect reasonable compromises.

Given those caveats, the consistent estimated concavity of the utility function across space supports the notion that fishermen are risk averse, at least in the limited (narrow bracketing) sense of the analysis. However, even within risk averse fishers, there was spatial variation. Across all measures of risk aversion, the greatest occurred at the ends of the geographic range of the fishery, whereas the smallest occurred in the center of distinct areas, such as North Carolina, on the Atlantic, and the Florida Keys. This may be a function of preferences of the fishers and the choices available in different areas, but it could also arise from circumstances that were not considered. Being at the geographic extreme may make fishers more dependent on other fishery alternatives. If other fishing opportunities were included in the choice set, the results might change.[12]

The consistency in the order of magnitude of the median risk premium per day at sea lends support to the results of the analysis. While there was considerable variation, a risk premium of less than $75 per set was found. This represented less than 11% of the set costs to the boat. Although the fishers are, on average, risk averse, the implicit costs of the risk to them were estimated to be within the costs that they incur on a normal trip.

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[12] In the survey conducted by Porter *et al.* (2001), respondents in New York did not indicate other fishing activities beside longlining, suggesting that exclusion of other fishing opportunities did not affect the results.

Finally, substantial differences were found when the entire sample was pooled. In general, the pooled sample's results indicated less sensitivity to the expected values and variance. This would suggest that the costs of policies, such as area closures, are overestimated with a spatially aggregate model. Thus, there is a danger of aggregation bias when not recognizing spatial heterogeneity in fisheries.

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